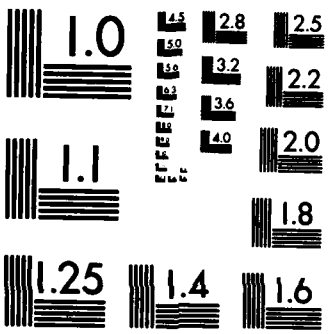
AD-A137 030 N1 AND P1 COMPONENTS OF THE VISUAL EVOKED RESPONSE IN HUMANS A TOPOGRAPHI..(U) TECHNOLOGY INC SAN ANTONIO TX LIFE SCIENCES DIV F H PREVIC ET AL. NOV 83 1/1

UNCLASSIFIED TR-118B-6183 SAM-TR-83-44 F33615-80-C-0610 F/G 6/16 NL



(12)

Report USAFSAM-TR-83-44

AD A137030

N1 AND P1 COMPONENTS OF THE VISUAL EVOKED RESPONSE IN HUMANS: A TOPOGRAPHICAL AND FUNCTIONAL COMPARISON

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November 1983

Final Report for Period 1 January 1983 - 1 May 1983

Approved for public release; distribution unlimited.

Prepared for
USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

NOTICES

This final report was submitted by Life Sciences Division, Technology Incorporated, 300 Breesport, San Antonio, Texas, under contract F33615-80-C-0610, job order 7757-02-70, with the USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas. Dr. Ralph G. Allen (USAFSAM/RZV) was the Laboratory Project Scientist-in-Charge.

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The voluntary informed consent of the subjects used in this research was obtained in accordance with AFR 169-3.

The Office of Public Affairs has reviewed this report, and it is releaseable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: USAFSAM-TR-83-44

2. GOVT ACCESSION NO.:

3. RECIPIENT'S CATALOG NUMBER:

4. TITLE *(and Subtitle)*: N1 AND P1 COMPONENTS OF THE VISUAL EVOKED RESPONSE IN HUMANS: A TOPOGRAPHICAL AND FUNCTIONAL COMPARISON

5. TYPE OF REPORT & PERIOD COVERED: Final Report, 1 January - 1 May 1983

6. PERFORMING ORG. REPORT NUMBER: TR-118B-6183

7. AUTHOR(s): Fred H. Previc, Ph.D.; David L. Schafer, B.S.; Cheri A. Spencer, B.S.; and James A. Chambers, B.S.

8. CONTRACT OR GRANT NUMBER(s): F33615-80-C-0610

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Life Sciences Division
Technology Incorporated
300 Breesport, San Antonio, Texas 78216

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
62202F
7757-02-70

11. CONTROLLING OFFICE NAME AND ADDRESS:
USAF School of Aerospace Medicine (RZV)
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

12. REPORT DATE: November 1983

13. NUMBER OF PAGES: 12

14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*:

15. SECURITY CLASS. *(of this report)*: Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT *(of this Report)*:
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*:

18. SUPPLEMENTARY NOTES:

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*:
Human pattern vision
VER components
VER

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*:
The N1 and P1 components of the visual evoked response (VER) in humans were compared along several dimensions. To elicit the VER, square-wave gratings were presented in pattern-appearance/disappearance and phase-reversal stimulation modes. The gratings varied in terms of contrast, spatial and temporal frequency, and the region of the visual field in which they were presented. The results of these experiments indicated that the N1 and P1 components of the human VER possess similar functional and topographical characteristics, and may reflect a common neural origin.

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N1 AND P1 COMPONENTS OF THE VISUAL EVOKED RESPONSE IN HUMANS: A TOPOGRAPHICAL AND FUNCTIONAL COMPARISON

INTRODUCTION

The visual cortical response to patterned visual stimuli (commonly referred to as the visual evoked response, or VER) has been widely studied and utilized in assessing visual function in humans and monkeys (1-7). No study, however, has systematically compared monkey and human VERs under identical stimulation parameters. In previous research conducted by this laboratory (8), VERs obtained from three rhesus monkeys and six humans were compared with respect to their basic waveforms. The two sets of VERs were similar to the extent that both possessed a P1 (positive) component that peaked between 80 and 110 ms after the onset of a square-wave grating (Figure 1). However, none of the monkeys (one of which had a bipolar recording electrode implanted in its left striate visual cortex) exhibited a preceding N1 (negative) component which was elicited in all six human subjects.

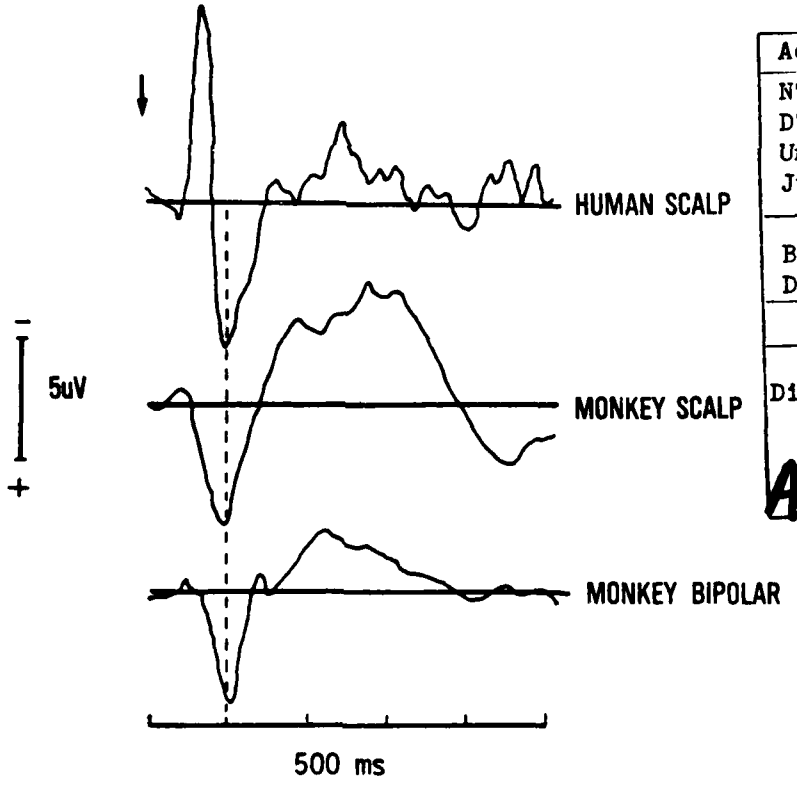

Figure 1. A comparison of human (subject JZ), monkey monopolar (194Z), and monkey bipolar (298D) VERs. Each VER was elicited by the onset of a 4.0-cycles/degree (c/deg) square-wave grating. Viewing conditions were identical except that monkey viewing was monocular (right eye) whereas human viewing was binocular. (8)

A barbiturate anesthetic was used in the monkey experiments, but subsequent recordings from one of the monkeys indicated that the absence of the N1 component was probably not due to the anesthetic because no fundamental change in the VER waveform was observed across varying anesthesia depths (Figure 2).

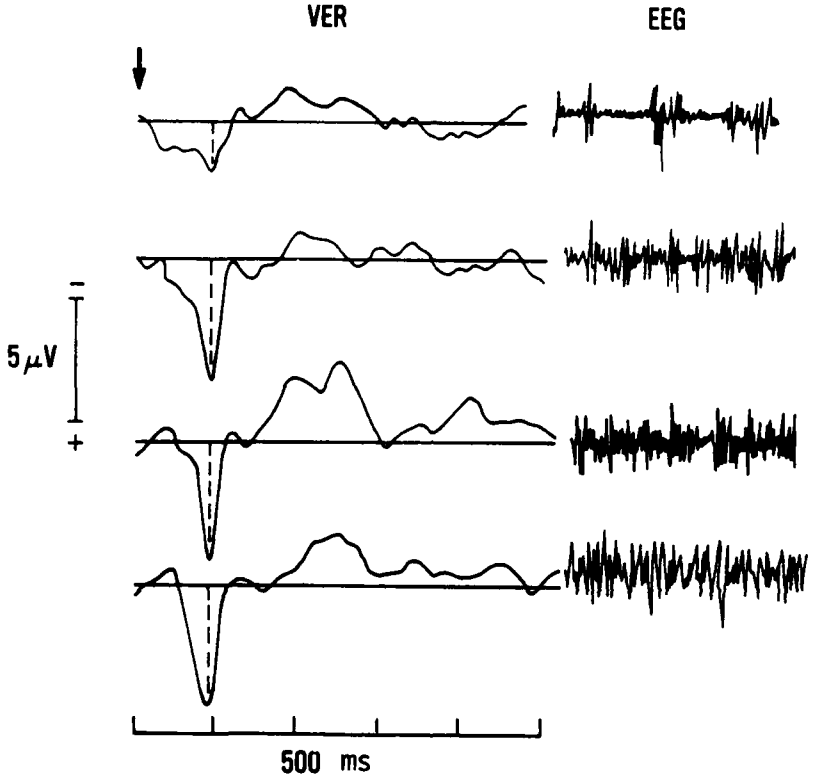

Figure 2. Effect of anesthesia level upon the monkey bipolar VER. Each VER was recorded from subject 298D in response to the onset of a 4.0-c/deg square-wave grating. Greatest depth of anesthesia is shown at top and is characterized by spindling in the EEG. (8)

The purpose of the present study was to determine if the N1 and P1 components of the human VER are indeed distinct components, and if any differences in their functional and topographical characteristics might explain the apparent lack of the N1 in the monkey.

METHOD

Subjects

Six adult humans served as volunteer subjects in four experiments. They were military or civilian personnel at the U.S. Air Force School of Aerospace Medicine (USAFSAM), Radiation Sciences Division, Vulnerability Assessment Branch. All subjects possessed binocular visual acuities equal to or better than 20/25.

Procedure

Visual Stimulation

The stimuli used in these experiments were square-wave gratings contained in a 12-deg circular stimulus field. The stimuli were generated by means of a PDP 11/34 computer in conjunction with a Technology Incorporated video stimulator unit, and were displayed on an Aydin video monitor. The fundamental spatial frequency of the gratings was set at one of the following values: 1.0, 2.0, 4.0, or 5.7 cycles/degree (c/deg). Contrast, as defined by the formula $C = (L_{max} - L_{min})/(L_{max} + L_{min})$, was either 0.40 or 0.70. Two types of temporal modulation were employed: pattern appearance/disappearance (in which the grating alternated with a blank field of the same average luminance) and phase reversal (counterphase). The pattern-appearance/disappearance stimulation frequency was 1 Hz, whereas the counterphase frequency was either 1, 3, or 5 Hz.

Each of the stimuli possessed a narrow spectral bandwidth centered at 540 nm, and an average luminance of 30 cd/m^2. Subjects viewed the stimuli binocularly in a darkened chamber at a distance of 1 m. A small spot placed on the stimulus screen aided subjects in maintaining central fixation.

VER Recording

The VERs were elicited either by the zero phase of each phase-reversing grating or by the grating's onset during the pattern-appearance/disappearance stimulation. The source electrode was a silver/silver-chloride cup electrode placed 2.5 cm above the inion, on the midline. Reference and ground electrodes were attached to the right and left earlobes respectively. The various electrodes were attached by means of Grass EC-2 electrode cream, which helped to maintain resistances below 10,000 ohms.

Visual cortical activity was recorded in an electrically shielded chamber and amplified by Grass 7P511 solid-state amplifiers. The amplification gain was 20,000, with low and high frequency filters set at 1 and 100 Hz respectively. A Nicolet 1070 computer averaged 128 individual 512-ms epochs in generating each VER. The averaged records were then plotted on a Hewlett-Packard 7001-AMR X-Y plotter.

Overall Design

The four experiments in the present study were designed to investigate the topographical locus, spatial- and temporal-frequency tuning, and contrast dependence of the N1 and P1 components. The rationale for the topography and contrast experiments was based on previous reports suggesting that the two components might differ along these dimensions (3,9). The spatial- and temporal-frequency tuning experiments were selected because these parameters are routinely used to assess visual function.

Square-wave gratings presented in the pattern-appearance mode were used as stimuli in all but the temporal-frequency tuning experiment. In that experiment counterphasing gratings were used because quantifying the grating-appearance response at higher temporal frequencies would have been difficult. In the topography experiment, VERs were elicited under full-field (0-12 deg), central (0-6 deg), and peripheral (6-12 deg) viewing. In the spatial- and temporal-frequency tuning experiments, four spatial frequencies (1.0, 2.0, 4.0, and 5.7 c/deg) and three temporal frequencies (1, 3, and 5 Hz) were used to elicit the VER. The contrast experiment consisted of three conditions: increasing high (grating onset at 0.70 contrast), increasing low (grating onset at 0.40 contrast), and decreasing high contrast (grating offset at 0.70 contrast).

The order of conditions within each experiment, as well as the order of the experiments themselves, was counterbalanced across subjects. The various conditions within each experiment were presented in reverse order for each subject during a replication run. For a given subject, the entire set of experiments was completed within a single 2-h session.

RESULTS

The N1 and P1 components and the manner in which they were measured are illustrated in Figure 3. The basic VER waveform elicited by a 4.0-c/deg grating appearing and disappearing at a rate of 1 Hz was highly consistent across subjects. In all but the temporal-frequency experiment, the N1 component was defined as the maximum negativity (relative to a 40-ms baseline), occurring 65-95 ms post stimulation; whereas the P1 component was defined as the maximum positivity, occurring 80-125 ms post stimulation. Because of the lack of a true baseline at higher counterphase frequencies (Figure 4), the amplitude of the N1 and P1 components in the temporal-frequency experiment was measured relative to peak onset rather than baseline. Repeated-measures analyses of variance were used in analyzing the results of the four experiments.

Results of the topography experiment are shown in Figure 5. The N1 and P1 amplitudes were greatest during full-field viewing, with both the central and peripheral visual fields contributing substantially to the full-field response. The portion of the visual field which was stimulated had a highly significant ($F(2,10) = 31.49$, $p < .001$) effect, but the interaction between VER component and visual field was not significant ($F(2,10) = 2.40$, $p > .10$). The N1 component did appear, however, to be more attenuated than P1 during peripheral viewing, a trend that was manifested in five of the six subjects.

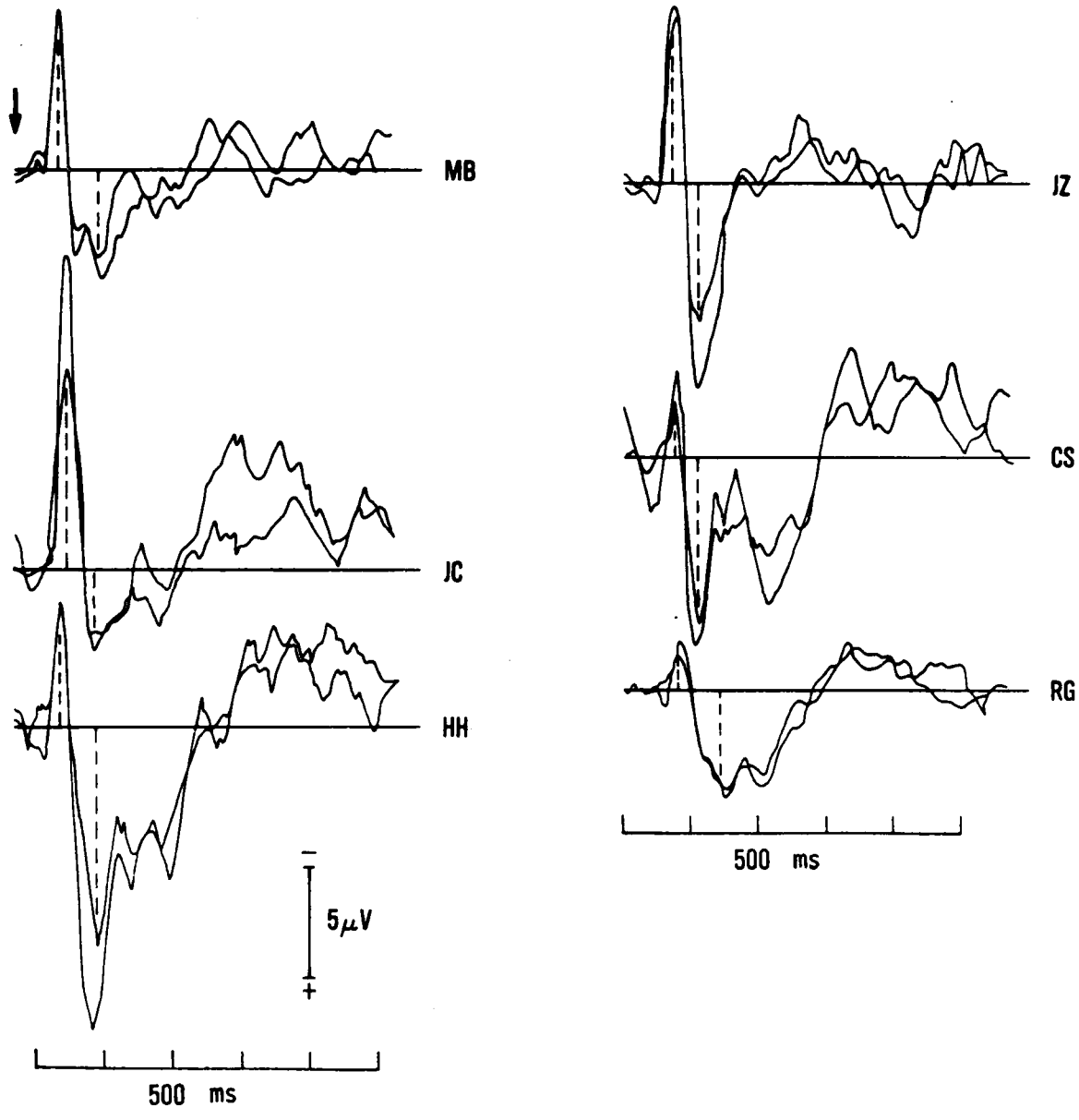

Figure 3. VERs recorded from each of six human subjects. Each VER is based on an average of 128 responses elicited by the onset of a 4.0-c/deg square-wave grating. Dotted lines indicate the approximate latencies at which N1 and P1 amplitudes were measured.

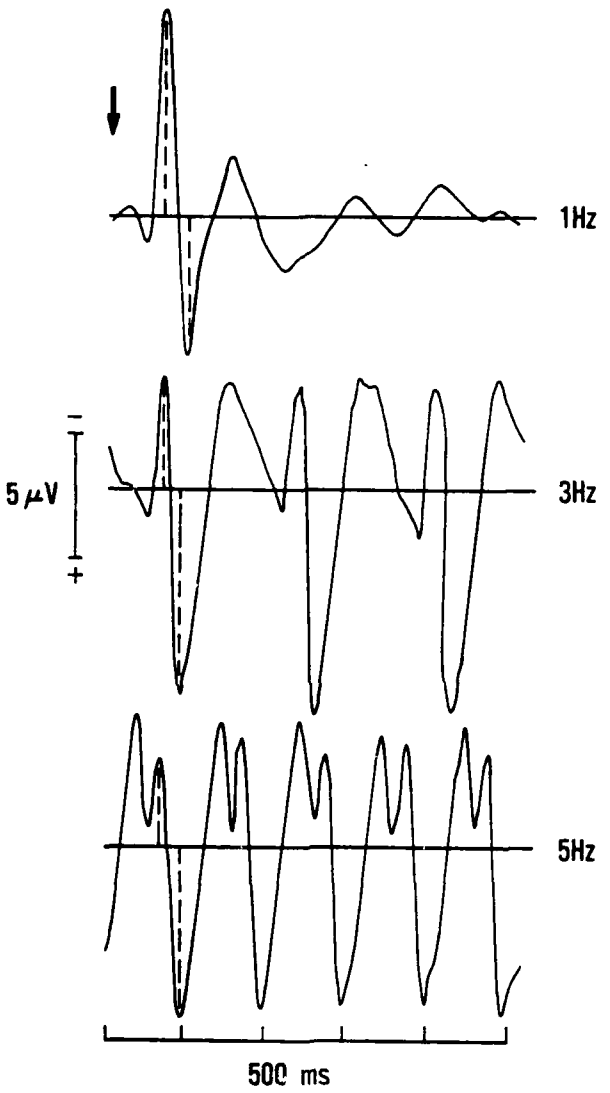

Figure 4. Effect of temporal frequency upon the VER. VERs were recorded from subject JZ and are based on an average of 128 responses elicited by a counterphasing 4.0-c/deg square-wave grating. Dotted lines indicate the approximate latencies at which the N1 and P1 components were measured, relative to peak onset.

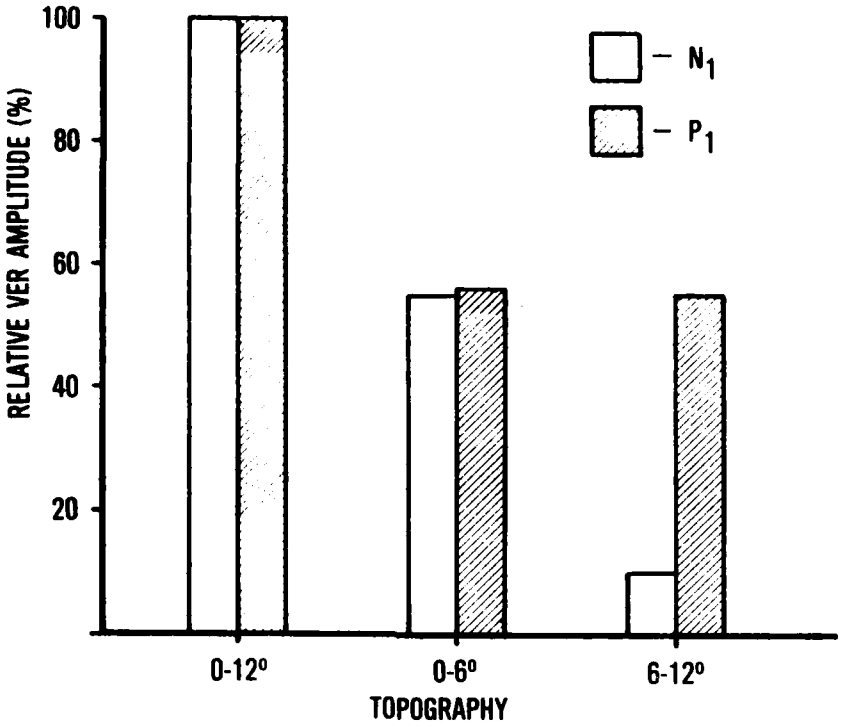

Figure 5. Relative N1 and P1 amplitudes as a function of the visual-field region that was stimulated. The data are averaged across six subjects and two replications.

Figure 6 displays results of the examination of the spatial-frequency tuning characteristics of the N1 and P1 components. Both components were greatest in amplitude at the highest spatial frequency used (5.7 c/deg) and monotonically declined as spatial frequency decreased. This result generally concurs with psychophysical estimates of spatial-frequency responsiveness over this frequency range (10). The analysis of variance revealed a significant effect of spatial frequency ($F(3,15) = 23.07$, $p < .001$) and a nonsignificant "component x spatial frequency" interaction effect ($F(3,15) = 0.61$, $p > .10$).

The amplitudes of N1 and P1 across temporal frequency are shown in Figure 7. The two components monotonically decreased in amplitude as temporal frequency increased, as reflected in a significant effect of temporal frequency ($F(2,10) = 21.09$, $p < .001$). The N1 amplitude diminished more rapidly with increasing temporal frequency than did the P1 amplitude, although this trend (manifested by five of six subjects) did not achieve statistical significance ($F(2,10) = 0.62$, $p > .10$).

Results of the contrast experiment are depicted in Figure 8. The difference between the increasing and decreasing high-contrast conditions--in which the total amount of local-luminance change was held constant--shows that both major VER components were clearly sensitive to changes in stimulus contrast. This finding is consistent with those of a previous study in which a difference was noted between the grating-onset and grating-offset responses (11). The

fact that the onset of a 0.70-contrast grating elicited a greater VER than did the onset of a 0.40-contrast grating demonstrates that contrast values greater than 0.40 are required to saturate the VER under the stimulation parameters used in this study. The analysis of variance revealed a significant effect of contrast condition ($F(2,10) = 14.74$, $p = .001$) and a nonsignificant "component x contrast" interaction effect ($F(2,10) = 0.65$, $p > .10$).

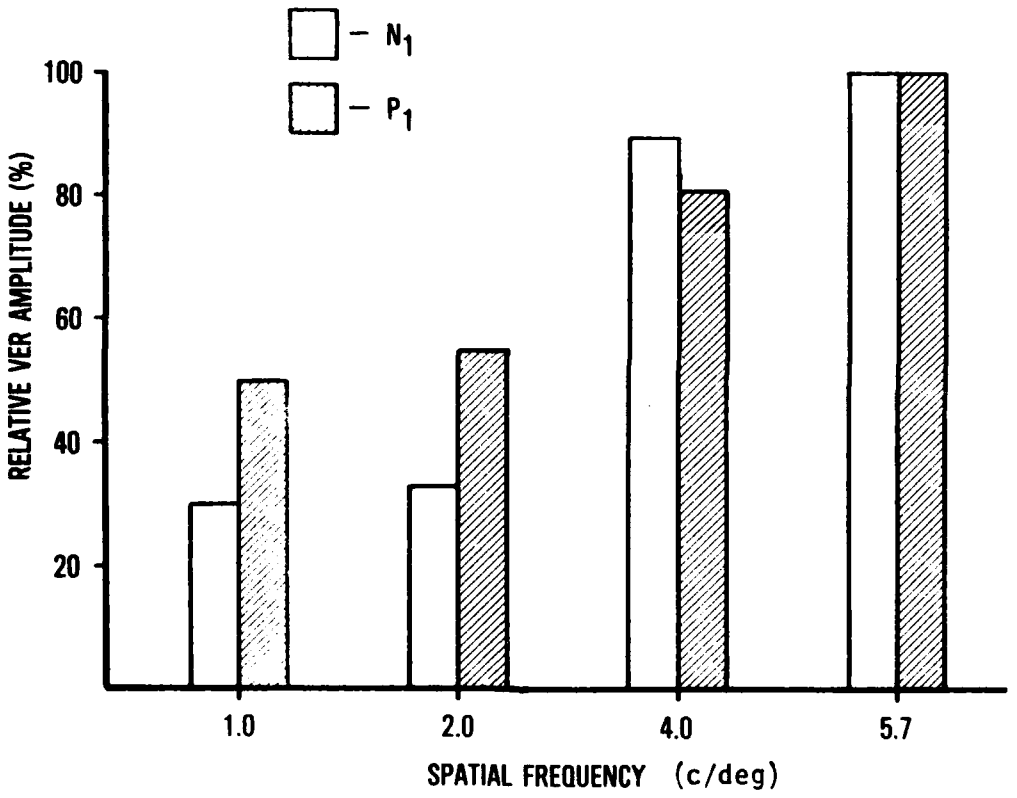

Figure 6. Relative N1 and P1 amplitudes as a function of spatial frequency. The data are averaged across six subjects and two replications.

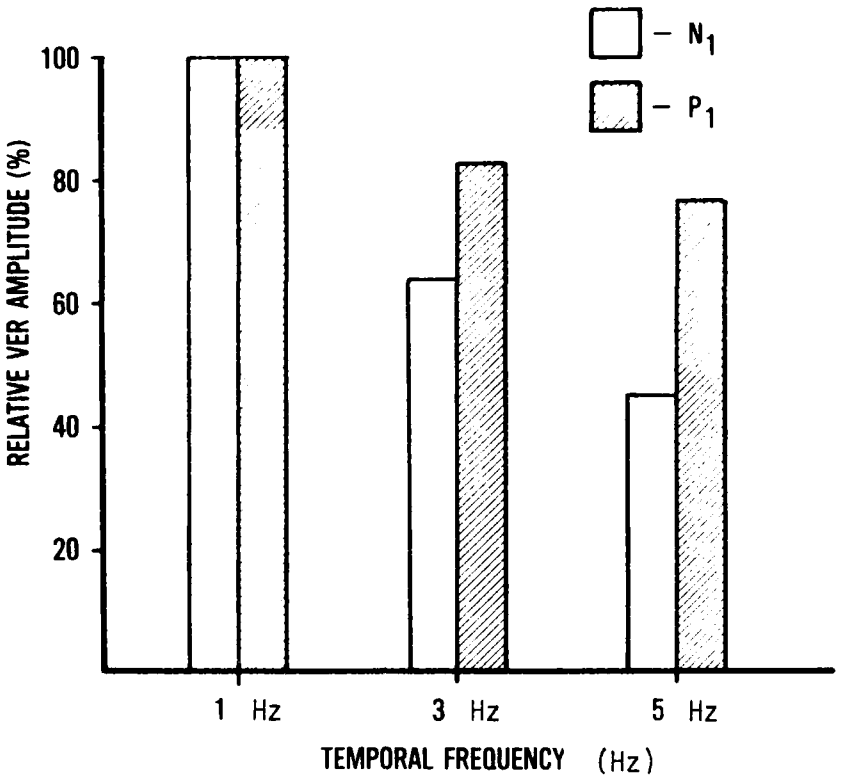

Figure 7. Relative N1 and P1 amplitudes as a function of temporal frequency. The data are averaged across six subjects and two replications.

DISCUSSION

The results of these experiments suggest that the N1 and P1 components of the human VER do not differ significantly in terms of any of the topographical or functional characteristics assessed in this study. It is possible that a subject population larger than that used in this instance may reveal significant differences between the components; also, N1 and P1 may differ along dimensions that were not investigated in these experiments. The present results alone, however, do not indicate that N1 and P1 are distinct components, nor do they suggest why only the P1 component is apparent in the monkey VER during pattern-appearance stimulation.

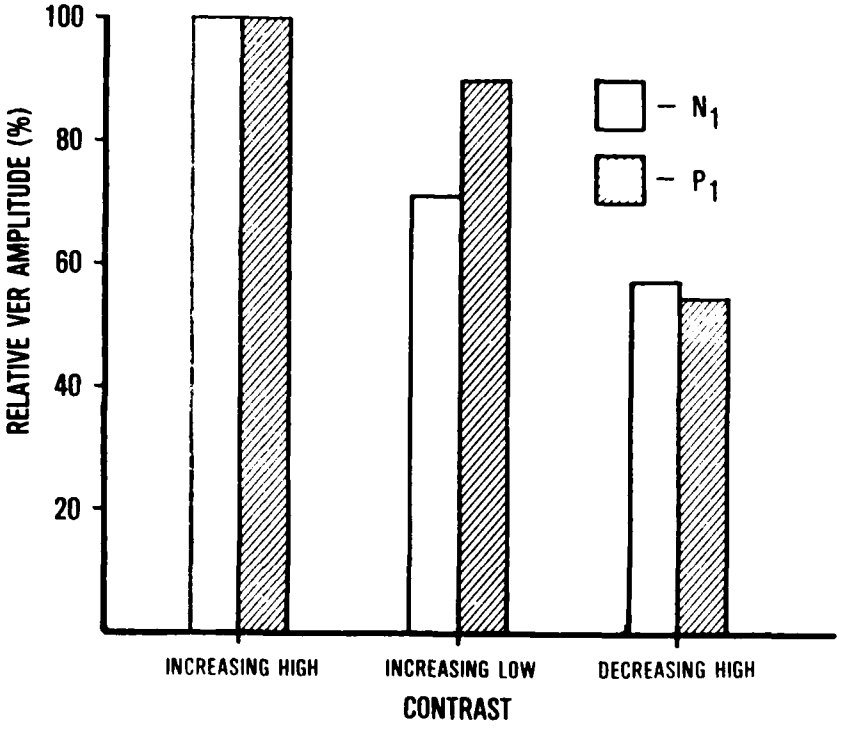

Figure 8. Relative N1 and P1 amplitudes under three contrast conditions: increasing high, grating onset at 0.70 contrast; increasing low, onset at 0.40; decreasing high, offset at 0.70. The data are averaged across six subjects and two replications.

These findings are in conflict with previous reports that have noted differences between the N1 and P1 components (3,9,12). For instance, a recent study argued that N1 is elicited by more peripheral portions of the visual field than is P1 (9), and a previous study suggested that a component possessing a latency similar to that of N1 is more sensitive to stimulus contrast than a component peaking at approximately 100 ms (3). However, the stimuli used in the previous studies were not square-wave gratings, so it is not entirely clear whether their components were identical to those termed N1 and P1 in the present study.

If, despite their functional and topographical similarity, the N1 and P1 components are truly distinct, at least two possibilities exist as to why N1 is recorded concomitantly with P1 in the human but not in the monkey. First, N1 and P1 may originate in extrastriate and striate visual cortex respectively. In the human the boundary between area 17 and extrastriate visual cortex is located near the longitudinal fissure, so a midline scalp electrode probably records both striate and extrastriate visual activity (3,13). In the monkey, the striate-extrastriate boundary is located more laterally, and the extrastriate visual cortex is embedded in the lunate sulcus (14), so recording extrastriate visual activity may be more difficult. Second, the relative time-courses of N1 and P1 suggest that they may reflect the activity of precortical and cortical components, respectively, of the same sensory projection system. If the monkey VER in general and the monkey bipolar VER in particular largely reflect the activity of the cortical components of this system, the failure to record N1 in the monkey could occur. Unfortunately for both of the above hypotheses, no conclusive evidence exists concerning the neural origins of N1 and P1 in the human.

ACKNOWLEDGMENT

The assistance of Richard C. McNee and Carolyn J. Oakley of the USAFSAM Advanced Analysis Branch is gratefully acknowledged.

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